(BW/BW_{mean}) and tibia length (l/l_{mean}), according to the axial force or moment generated about the tibial midshaft by the ground reaction force. Scaled values were averaged over the entire middle third section for each subject, and group means were calculated and are reported in the table.

In the tibia, the mean A*, Imax* and J* values were significantly higher in runners for both age groups. There was no dependence on age for any of the measurements. Interestingly, the fibula did not show corresponding changes. We postulate that high loads associated with running lead to increased bone structural parameters to support axial loads (A), bending (Imax), and torsion (J) in the tibia.

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TABLE 1. MEAN VALUES FOR TIBIA AND FIBULA

		Tibia				Fibula			
Group	**n**	**A* (cm^2)**	**Imax*(cm^4)**	**Imin*(cm^4)**	**J* (cm^4)**	**A* (cm^2)**	**Imax*(cm^4)**	**Imin*(cm^4)**	**J* (cm^4)**
EHL	5	[a]2.548	[a]1.764	0.763	[a]2.527	0.528	0.129	0.031	0.160
ELL	7	1.991	1.094	0.594	1.688	0.492	0.101	0.028	0.129
YHL	5	[a]2.556	[a]1.549	0.748	[a]2.297	0.550	0.117	0.023	0.140
YLL	9	2.004	1.113	0.593	1.706	0.523	0.135	0.026	0.163

*Indicates scaled values; [a]$P < 0.05$.

BIOASTRONAUTICS RESEARCH

NASA Virtual GloveboX (VGX): Advanced Astronaut Training and Simulation System for the International Space Station

Jeffrey D. Smith, Richard Boyle

In the coming years, the International Space Station (ISS) will provide a permanent microgravity laboratory for biological research in space. From this orbital laboratory, astronaut crews will carry out complex life science experiments designed to answer long-standing questions concerning life's ability to adapt and respond to the space environment. Many of these experiments will require the use of the Life Sciences Glovebox (LSG). Within the LSG, astronauts must manipulate scientific instruments, perform experimental assays, collect tissue specimens and record biological data—all under highly controlled conditions and within strict time constraints. These experiments often demand extensive training and knowledge of instrumentation, anatomy, and specific scientific objectives. Furthermore, astronauts must remain highly proficient but, due to scheduling constraints, they can receive only limited Earth-based training with LSG mock-ups and real experiment specimens.

Also, the Earth-based training that astronauts receive may occur months prior to the mission, and they can never fully practice these procedures under microgravity conditions. These difficulties place very high demands on astronaut crews and also a very high level of risk on LSG experiment success.

The NASA Virtual GloveboX (VGX), being developed at Ames Research Center, combines state-of-the-art software and technology to provide astronauts and support crews with a realistic simulation environment for performing biological research in space. The VGX, shown in the first figure, is modeled after the Life Sciences Glovebox, making it fast and easy to plan experiments, develop procedures, and train and troubleshoot various experimental scenarios that astronauts may encounter when aboard the ISS. The VGX integrates off-the-shelf hardware with new real-time simulation technologies to make this realistic training and simulation tool possible. Two ultra-high resolution projectors run in synchronization with stereo glasses to produce a detailed three-dimensional scene within the glovebox work area, as shown in the second figure. Astronauts or technicians use a variety of three-dimensional tracking and/or force feedback devices to interact with computer-generated objects in the virtual environment. Moving experimental equipment in and out of the work area can be done at the click of a button; or, in a simulated experiment, the operator may be required to unlock door latches and open compartments to move equipment or experimental specimens in and out. Using the VGX, experiment developers can determine the optimal layout of experimental equipment, and quickly refine protocols by simulating experiments many times without the need for repeated set-up and break-down. Once procedures have been developed, astronauts can use the VGX as a training tool to practice a variety of tasks quickly and easily. They may also use it to train on off-nominal situations and to refresh themselves on critical experimental procedures when time is short or when other training facilities are unavailable.

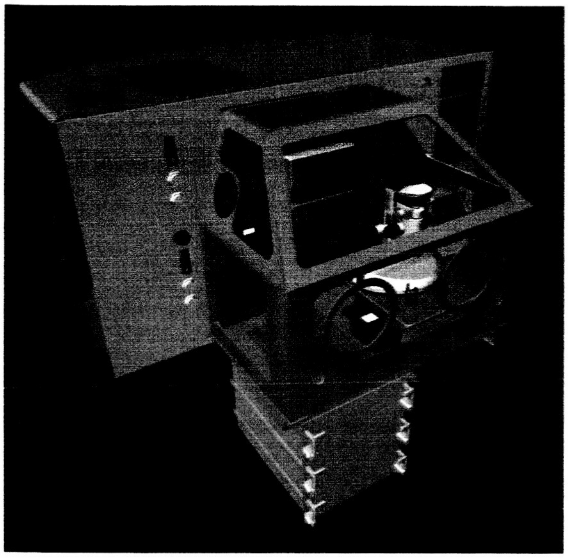

Fig. 1. The NASA Virtual GloveboX (VGX) combines virtual environment technologies and simulation engines to produce a realistic engineering experiment development and astronaut training tool for biological research in space. The VGX is shown here deployed from the Life Sciences Glovebox rack with an animal habitat attached below. A microscope and experimental equipment are placed inside the glovebox work area.

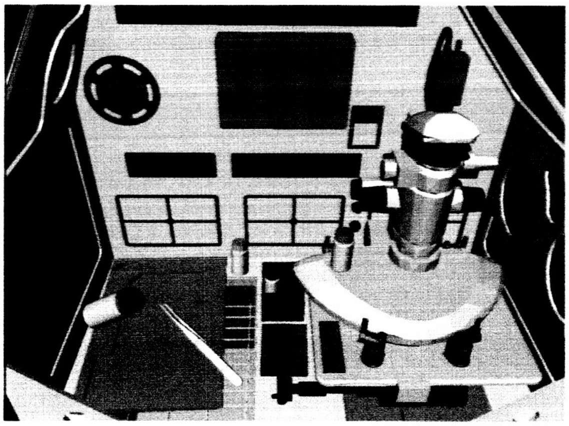

Fig. 2. Experiment development and simulation within the glovebox allows for manipulation of high-resolution models of actual equipment and supplies that will be used for biological research in space. A stereo microscope with CCD camera attached and several vials, tweezers, and a pad of gauze are shown in this depiction. The door to the animal habitat attached below the glovebox is pushed aside to reveal a portion of the habitat cage.

The VGX will maximize the efficiency of glovebox experiment planning, operations, training, and trouble-shooting for astronauts and support crews, thus greatly reducing the risks associated with Space Station glovebox experiment success. With the realistic simulation environment of the VGX, gravity can be turned on and off, allowing astronauts to practice experiments in a simulated real-time microgravity environment while still on Earth. This represents a significant advancement over current training methods which must be developed and practiced entirely on Earth under its constant unit gravity acceleration.

In a continuing effort to improve the VGX, many new advances in virtual environment computing and technologies are also being developed which push NASA to the forefront in real-time visual/haptic simulation and computing research. The resulting VGX simulation system helps solve NASA's glovebox development and training requirements, but at the same time, it provides a generalized simulation engine for any immersive environment application, such as biomedical/surgical procedures for interactive scientific or engineering applications. For NASA, the Virtual Glovebox can not eliminate the need for training on LSG mock-ups using real experiment equipment and real biological specimens; however, the VGX streamlines these processes and provides astronauts with a means to keep their skills sharp both on Earth and in space. With better ways to engineer, develop, and train for the many complex life science experiments that astronauts will perform onboard the ISS, Ames Research Center is paving the way to successful biological research in space.

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ADVANCED LIFE SUPPORT

Advanced Life Support Power Reduction

Cory K. Finn

This research involves modeling of the power and energy usage of regenerative life support systems suitable for exploring the Moon and Mars. System energy integration and energy reuse techniques are being investigated, along with advanced control methods for efficient distribution of power and thermal resources. The high power requirements associated with food production and overall closed regenerative system operation remain a critical technological challenge. Optimization of individual processors alone will not be sufficient to produce an optimized system; system studies must be used in order to improve the overall efficiency of life support systems.

Designs are being developed that match sources of waste heat—crop lighting and solid waste processing systems—with processes that can use this waste heat—water processing, food processing, food preparation, and heating water for showers, for washing dishes, and for washing clothes. Using energy integration techniques, optimal system heat exchange designs are being developed by matching hot and cold streams according to specific design principles. For various designs, the potential savings for power, heating and cooling are being identified and quantified, and estimates are being made of the emplaced mass needed for energy exchange equipment.